Discussion Group: Inertial Fusion Energy and Shocks

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-- What are the main areas where inertial fusion target topics can be explored on NDCX-II, GSI or other ion facilities?

-- Why use shocks?

-- Why or why not use ions?

-- What are some conceptual experiments for using ion driven shocks for determining material properties?

-- What are some tricks that can be used?

What are the main areas where inertial fusion target topics can be explored on NDCX-II, GSI or other ion facilities?

Ion beam coupling experiments (maximizing shock strength by ramping the ion energy on NDCX-II)

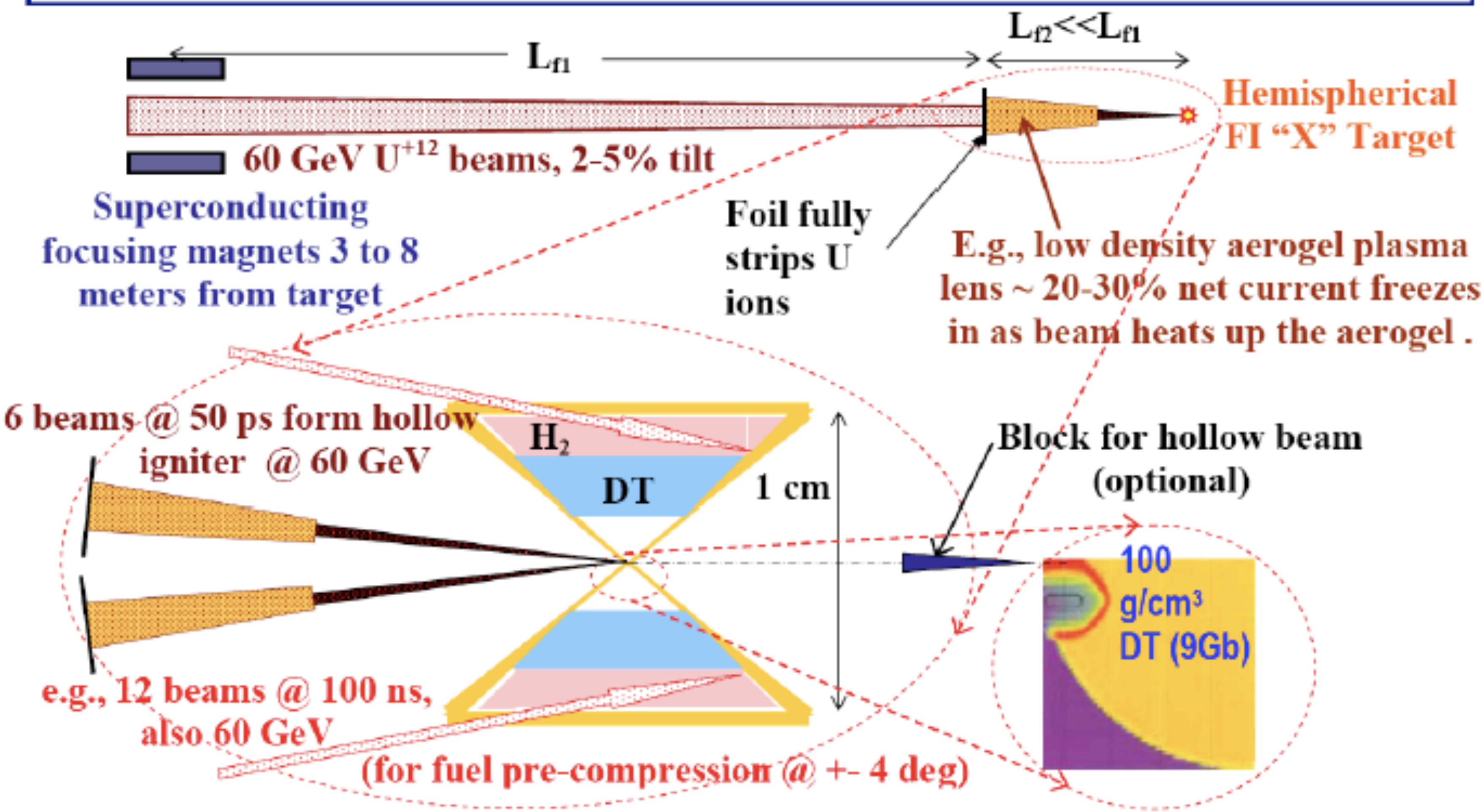
Ion driven shock stability (Richtmeyer-Meshkov instability, on both NDCX-II and GSI FAIR)

X-target assembly hydrodynamics (see next viewgraph)
-- could be done at GSI SIS-18 or NDCX-II)
-- On NDCX-II scale of conical holes ~ few microns, on GSI need scaled experiment (since pulse energy lower, but ion energy comp.)
-- Need wobbler in both cases

EOS relevant to IFE
-- HIHEX (planar foils) (pyrometer)
-- EOS: expansion of ion heated foils. Observation of intensity and velocity as function of frequency over time

Gain 500 heavy ion fast ignition concept ("X-target")

Two-steps: (1) Low density hemisphere DT fuel assembly e.g. 500-600kJ @ 60 GeV beams in ~100 ns, compressing DT to 100 g/cm^3 in efficient hydro-coupled regime. (2) Fast ignition with 300-500kJ, 60 GeV, 50-100ps, U^{92+} beams stripped in close-in (built-into-the-target B_θ) lens (two stage focusing with powered or self-pinches).



Why use shocks?

-- Automatically created in WDM regime (high rho, relatively low T (fraction of an eV)

-- Well defined state (measure velocity, know initial density) Rankin-Hugoniot conditions yield P, etc

-- New science of non-LTE shock front physics (shock heats ion from compression, electrons then follow, so front of shock is non-LTE. Processes such as solid/solid and solid/liquid phase change molecular dissociation, ionization, electron-ion relaxation process contribute to the complexity.)

-- Physics of instabilities (such as Richtmeyer-Meshkov instability)

-- Begin gaining experience as ion machine pulse energy increases

Why or why not use ions?

Any new platform is good science. (Can bridge from gas guns, to lasers, to ion machines)

Energy deposition is different than lasers, can give rise to different saturation, different relaxation processes

Preheat of unshocked material can be minimized because of volumetric energy deposition (X-rays not generated in a very short deposition length where T can be high)

Contrast ratio can be very high (since pulsed acceleration can minimize prepulse).

What is the role of thermal conduction? (Will thermal conduction heat -wave precede the shock for thin (~ 10 – 100 micron) targets). Sets minimum rise time.

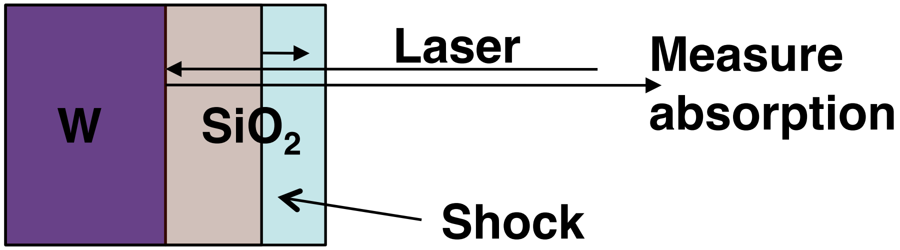
What are some conceptual experiments for using ion driven shocks for material properties?

-- Phase transition in Quartz. Requires 0.1 to 1.0 MBar. Check schlieren or shadow graph previous results. Possible use of visar at shock front. Will darkening be present?

-- LAPLAS (annular beam or solid circular beam, cylindrical shock compression at GSI FAIR)

-- Cylindrical or spherical bubbles (observe compression time scale to distinguish between equations of state) (at GSI and NDCX-II)

-- Measuring ionization behind shock front by observing reflecting laser probe (in transparent material)



What are some "tricks" that can be used?

-- Impedance mismatches: launch shock in low density (foam?); then propagate into a high density material (to increase shock strength)

-- Ramp wave (not shock): (creating high pressure at low adiabat)
Directly driven (ramp the intensity with time)
Reservoir driven (rapidly heat "reservoir" then use release of reservoir to heat second target to adiabatic compress it)

-- Ion driven flyer (accelerated foil to impact target) (Foil deforms, difficult to accelerate, ~ 1 km/s on NDCX-II (not great))

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Phil Heimann and Dick Lee are cochairmen

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Warm Dense Matter (WDM) refers to the broad regime of material states that occur between conventional condensed matter and plasmas that cannot be satisfactorily described by standard theory in either field. Matter density ranges from liquid to many times solid, temperatures comparable to the Fermi energy and above, and pressures that are consequently large. Capability in WDM is crucial for understanding the evolution of large planets, the dynamics of planetary collisions, and the transition of matter from a